

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.				
1. REPORT DATE (DD-MM-YYYY) 30-06-2011		2. REPORT TYPE Final Report		3. DATES COVERED (From - To) 01-01-2007 to 09-01-2007
4. TITLE AND SUBTITLE Train undergraduate and graduate students in the spacecraft design lifecycle through the Bandit-D mission: Collaborative situational awareness using a team of four deployable spacecraft			5a. CONTRACT NUMBER FA9550-09-1-0102	
			5b. GRANT NUMBER	
			5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Swartwout, Michael A.			5d. PROJECT NUMBER	
			5e. TASK NUMBER	
			5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Mechanical & Materials Engineering Washington University in St. Louis Campus Box 1185 1 Brookings Drive St. Louis, MO 63130-4899			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NE 4015 Wilson Boulevard Room 713 Arlington, VA 22203-1954 Attn: Univ. Nanosat Program			10. SPONSOR/MONITOR'S ACRONYM(S)	
			11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-OSR-VA-TR-2012-0721	
12. DISTRIBUTION / AVAILABILITY STATEMENT Unlimited Public Availabilty				
13. SUPPLEMENTARY NOTES				
14. ABSTRACT Undergraduate and graduate students at Washington University in St. Louis and Saint Louis University delivered a functional prototype of the Close-Orbiting Propellant Plume and Elemental Recognition (COPPER) spacecraft to the 2011 Flight Competition Review of the University Nanosat-6 Program. In addition to the design reviews and events sponsored by the Program, the major accomplishments of this grant activity include: 1) Transitioning the program from Washington University to Saint Louis University (where the PI completed the work as a subcontract), 2) Performing three major design revisions based on industry feedback and test results, 3) Having a re-scoped COPPER spacecraft be selected for launch on NASA's ELANA-IV flight in Spring 2012. 4) Building a core competency in space systems at Saint Louis University sufficient to be selected for the University Nanosat-7 Program 5) Loaning Akoya (original Nanosat-6 mission) to AFRL for SSA testing				
15. SUBJECT TERMS University Nanosat, Space Situational Awareness, Student-built satellite				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT none	18. NUMBER OF PAGES
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified		
				19a. NAME OF RESPONSIBLE PERSON Michael Swartwout
				19b. TELEPHONE NUMBER (include area code) 314-977-8214

Objectives

The original objectives of this proposed work have been significantly changed, based on discussions with the University Nanosat Program managers. In brief, the scope of the original project was deemed to be beyond the capabilities of the transitioning project team, and subsequent ground testing and project reviews led to several significant rescopes. Therefore, the modified objectives have become:

- The primary mission, COPPER, was to evaluate the effectiveness of long-wavelength infrared imagery for space situational awareness, specifically:
 - Launch a combined 3U CubeSat.
 - Separate the vehicle into a 1U imaging spacecraft (COPPER-Cube) and a 2U test spacecraft (COPPER-Tube)
 - Command COPPER-Tube to release propellant while in view of COPPER-Cube's imaging system
 - Relay images to the ground for analysis
- The secondary, non-flight mission was to transition infrastructure and space systems capabilities from Washington University (WUSTL) to Saint Louis University (SLU), since WUSTL is drawing down its space systems program, and the PI has moved to SLU. The success of this objective would be measured by:
 - Continued participation/completion of NS6 tasks by SLU students, aided by WUSTL legacy students.
 - Placement of participating WUSTL and SLU students in aerospace careers.
 - Success of the SLU program in winning competitive space systems awards (e.g., Nanosat-7, NASA ELANA, NASA Reduced Gravity)

Very late in the grant program (April 2011), AFRL contacted SLU about the possibility of providing Akoya (the protoflight spacecraft that would carry out the mission originally proposed under NS-6) for an extended period of time for use in SSA testing. That work was completed and Akoya is now residing at AFRL/RVSL.

Review of Efforts

Three sets of space hardware were developed during this grant period: Akoya and Bandit were started in the Nanosat-4 program, and have been improved, modified and repaired since then. As noted above, Akoya and Akoya GSE were modified for use by AFRL in a series of Space Situational Awareness (SSA) tests and delivered to AFRL in April 2011. Preliminary work was completed on the five-spacecraft COPPER concept during calendar year 2010; this work was briefed by SLU students at the Critical Design Review in Spring 2010 and again at the Protoflight Qualification Review in August 2011. Based on that feedback, the mission was de-scoped to fit inside a 3U ejector, resulting in the COPPER-Cube/Tube iteration. Hardware for this version was carried to functional demonstration status and presented at the 2011 Flight Competition Review.

In support of this work, the Space Systems Research Laboratory (SSRL) at St. Louis University was outfitted and staffed. SSRL now has hardware fabrication/testing stations, a Class-10,000 clean tent, vibration stands and vacuum chambers and, more importantly, has recruited and trained a core group of 15 students to lead development, test and operations activities at SLU. While the first true SSRL graduating class will not complete their studies until May 2012, students with SSRL experience are already moving into the aerospace workforce.

Leveraging the work accomplished and training acquired under this grant activity, SSRL faculty submitted to a number of AIAA and IEEE publications, as well as space-systems-related grant proposals to AFOSR, NSF, and NASA. (Results are summarized in the sections, below.)

Accomplishments/Findings

Pursuant to the Nanosat-6 Program activity, the WUSTL/SLU team completed all the required documents for the six reviews (System Concept Review, System Requirements Review, Preliminary Design Review, Critical Design Review, Protoflight Qualification Review, Flight Competition Review) and three activities (SHOT I, SHOT II and Satellite Fabrication Training). SLU students brought functional hardware to the Flight Competition Review.

In addition to the Nanosat-6 activities, the SSRL team leveraged the Nanosat Program training and accomplishments to win the following grant awards:

- NASA Educational Launch of Nanosatellites (ELANA) (2011 – Swartwout, PI). The COPPER-Cube spacecraft developed under NS-6 has been selected by NASA to fly in April 2012.
- AFOSR University Nanosat-7 (2011 – Swartwout PI). SLU has been selected to participate in NS-7.
- Missouri Space Grant Consortium Non-Affiliate Award (2009, 2010 – Swartwout, PI). This supplemental funding allowed additional students to participate in UNP activities.
- SLU President's Research Initiative (2009 – Swartwout, PI). This internal, competitive fund supplemented development of the infrared imaging system.

Personnel Supported

Supported Personnel. The following personnel received direct support from this contract:

- Dr. Michael Swartwout (PI) – 2 summer months (2009, 2010).
- Kerry Fessenden – summer intern (2010). Kerry is graduating in December 2011.
- Allison Cook – summer intern (2010). Allison is now working at AFRL.
- Colin Towery – summer intern (2009).
- Moira Evens – summer intern (2009).

Associated Personnel. The following students were funded to participate in contract activities, with the funding coming from other programs:

- Steve Massey (SLU support, 2010)
- Brian Verbus (SLU support, 2009, 2010)
- Alex Shim (SLU support, 2009)
- Will Sutton (SLU support, 2010)
- Maria Barna (SLU support, 2010)
- Niket Patel (SLU undergraduate research program, 2010)

Key Students. In addition to the students listed above, the following students made key contributions to the project, either through course work or volunteering in the summer: Kaitlin Burlingame, Katlyn Sullivan, Jeremiah Garrison, Kimberly Halom.

Publications

M. A. Swartwout. Perspectives in Critical Research Areas in Space Systems. *Journal of Aviation and Aerospace Perspectives*, 1(1), 2011.

M. A. Swartwout, S. Jayaram. The Argus Mission: Detecting Thruster Plumes for Space Situational Awareness. *IEEE Aerospace Conference Proceedings*, paper 1521, 2011.

M. A. Swartwout. A Brief History of Rideshares (and Attack of The CubeSats). *IEEE Aerospace Conference Proceedings*, paper 1518, 2011.

M. A. Swartwout. Attack of the CubeSats. *Proceedings of the 25th AIAA/USU Conference on Small Satellites*. Paper SSC11-VI-04, 2011.

S. Jayaram, M. A. Swartwout. A Review of the Role of Student-Built Spacecraft in Workforce Training and Innovation: Ten Years of Significant Change. *Proceedings of AIAA SPACE 2010 Conference and Exposition*. AIAA-2010-8735.

Interactions/Transitions

The PI moved from WUSTL to SLU in July 2009. The work continued at SLU under a subcontract to WUSTL.

The PI and one student (Cook) worked with Mr. Brian Engberg (AFRL/RVSL), to deliver the Akoya prototype to AFRL for environmental testing. Cook performed initial setup and tests, and continues to support the project as an RVSL civilian employee.

The PI and 4 students (all supported students) attended the 23rd Annual AIAA/USU Conference on Small Satellites in August 2009 and presented the COPPER mission at an exhibit booth. A significant fraction of the small satellite community attends this conference.

The PI and 6 students (including all supported students) attended the 24th Annual AIAA/USU Conference on Small Satellites in August 2010. They presented the COPPER mission. A significant fraction of the small satellite community attends this conference.

New discoveries

No new discoveries were made as a result of this grant activity.

Honors/Awards

No honors or awards were earned as a result of this grant activity (other than the grant awards noted above).